POLARIS: Agent-Based Modeling Framework Development and Implementation for Integrated Travel Demand and Network and Operations Simulations

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January 12, 2015

POLARIS

(Planning and Operations Language for Agent-based Regional Integrated Simulation)

- Initially Designed to:
  1. Model Traffic Control Centers and other ITS Systems
  2. Enhance Interoperability among Existing Tools
  3. Build on model integration efforts in travel demand

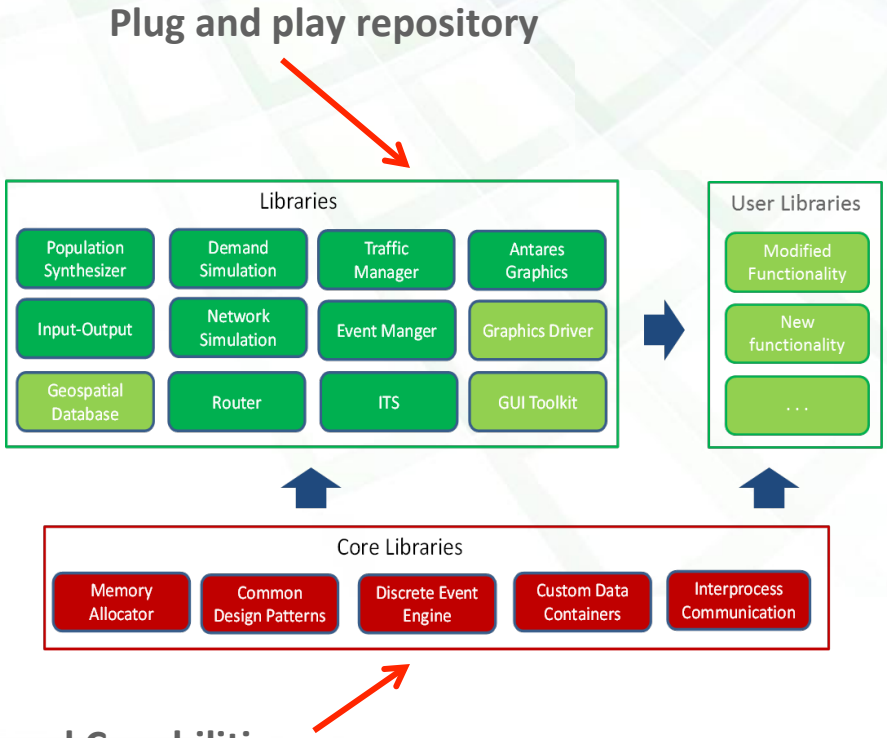
- Core Goals and Philosophies of the POLARIS Effort:
  - Develop Transportation Modeling Standards and Protocols
  - Create an Open Source Model Development Environment
  - Connect Sub-Communities with a Common Modeling Framework
  - Offer Helpful Tools while Maintaining Flexibility and Modularity
  - Enable high-performance transportation simulations

What is POLARIS?

- Middleware for Developing Agent-based Models
  - Data Interchange
  - Visualization
  - Case Study Generation and Analysis
  - Discrete Event Simulation
  - Memory Management

- A Repository of Transportation Libraries
  - Common Algorithms
  - Extended by Researchers
  - Standardized Style and Structure

- Fully Developed Applications
  - Transportation Network Simulation
  - Integrated Activity Based Travel Demand Simulation



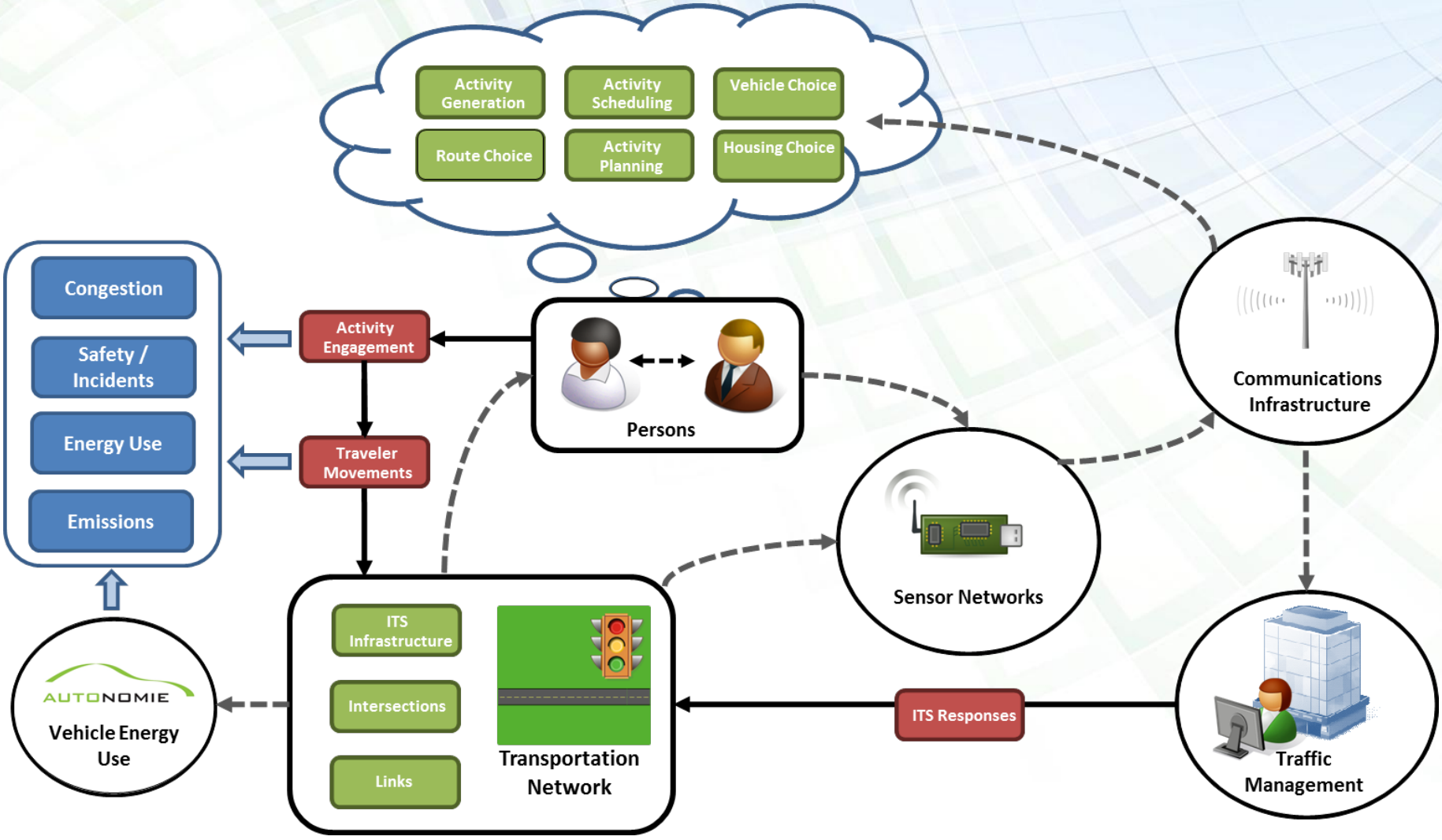
Agent-Based Modeling

- ABM is a well established methodology for studying complex systems that has been shown to provide a structure useful for modeling a vast array of phenomena:
  - social processes
  - software systems
  - manufacturing systems
  - urban dynamics

- In agent-based modeling:
  - Agent encapsulate a set of behaviors that govern their interactions with other agents and with their environment
  - Autonomous and are capable to adopt or modify behaviors
  - Allows system to be modelled from the bottom up

- Increased computer power allows for analyzing large scale systems
  - Transportation is a large-scale complex system so ABM seems appropriate

Overview of the Agent-Based Transportation System Model



Key POLARIS Activity-Based Model Components

- Agent Initialization
  - Population synthesis creates households / persons
  - Network / ITS agents read from system database

- Demand components
  - Generation, Planning and scheduling of activities to satisfy needs

- Network assignment / simulation
  - Agent-based, individualized route selection (multi-modal)
  - Simulation of travel on transportation network (auto only)

Disaggregate Integration

- ITS infrastructure and management simulation
  - Simulate ITS infrastructure operation
  - Management strategies (directly input or automated)

- Visualization and agent-interaction
  - View model through POLARIS GUI
  - Modify agent / infrastructure states

Agent Demand Based Largely on the ADAPTS ABM

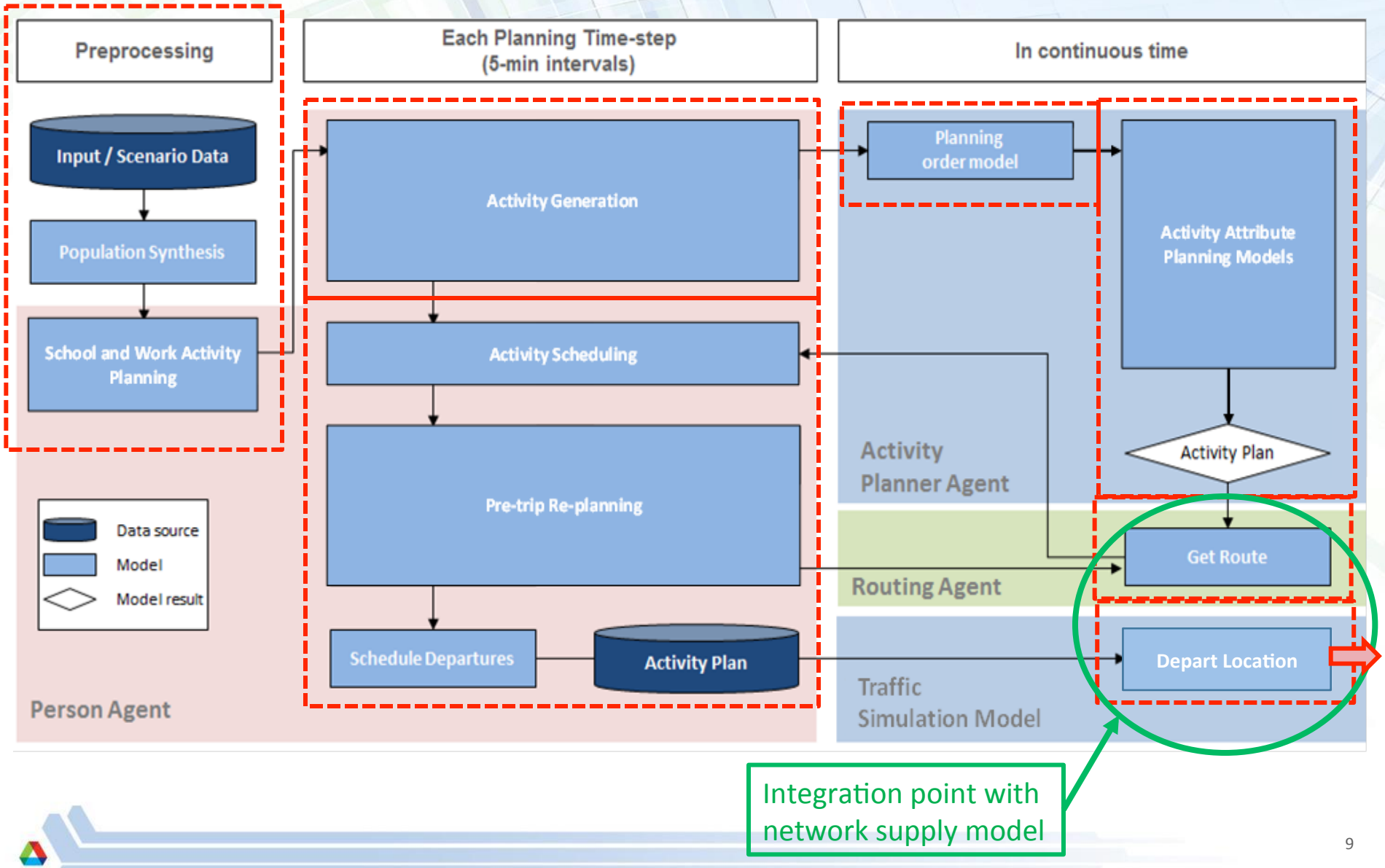
- ADAPTS activity-based model:
  - Simulation of how activities are planned and scheduled
  - Extends concept of “planning horizon” to activity attributes
    - Time-of-day, location, mode, duration, party composition
  - Dynamic generation and scheduling of activities

- Core concepts:
  - Set of activity planning / scheduling processes represented by heuristics and/ or models
  - Outcomes constrained by local context
  - Dynamic state dependence in decision making
  - Generation, Planning/ Replanning and Scheduling occur continuously in conjunction with traveling

Demand Components Implemented as Agent Behaviors

- Activity Generation: Create new activity episodes throughout the day
- Planning Order Model: Assign intrinsic episode characteristics
  - When are decisions about attributes made? How flexible are those decisions?
  - Allows for planning constraint in choice models to reduce set sizes
- Attribute planning models: Choice models determine attributes
  - Departure, destination, mode choice, routing – constrained by existing schedule
- Scheduling model: resolve conflicts and add activities to schedule
  - Use individual routed travel time when scheduling to reduce inconsistency
- En-route replanning
  - Bounded rationality model, triggered by information or excessive delay
  - Account for scheduling information when doing route switching
  - Replan due to unexpected events (i.e. weather, emergencies)

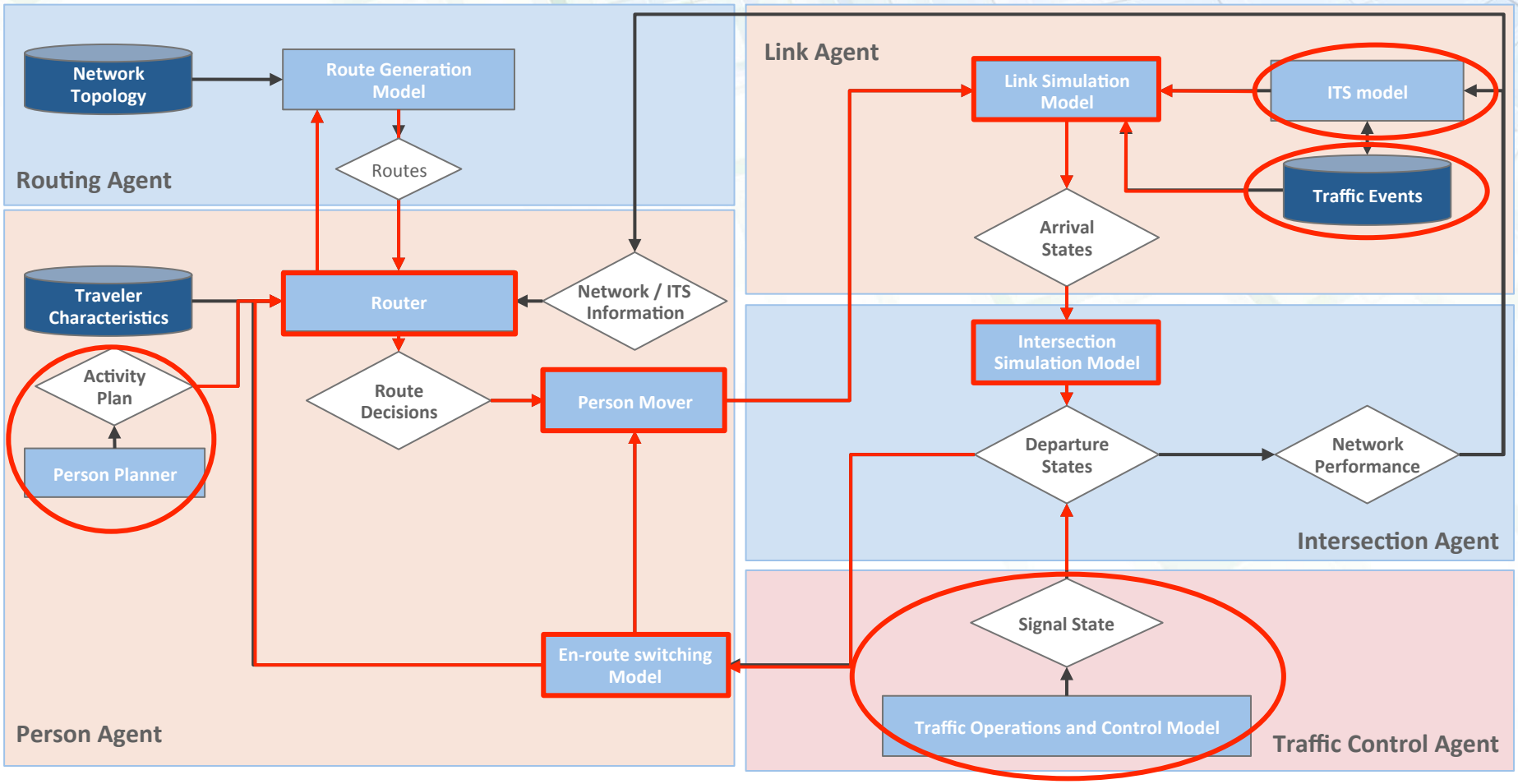
Simulation Flow in the Travel Demand Model



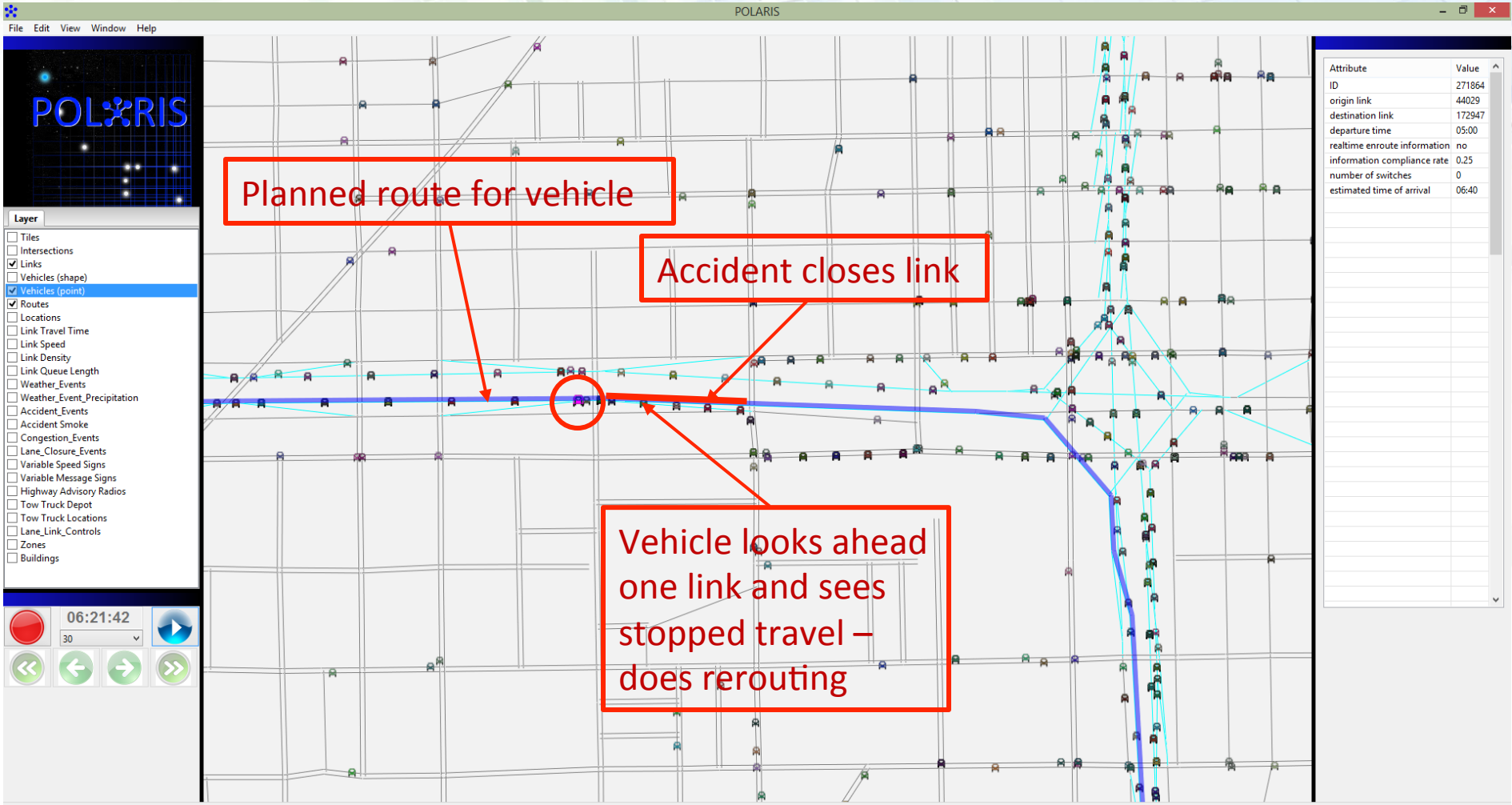
Simulation-Based Dynamic Traffic Assignment Model

- Mesoscopic Traffic Simulation Model
  - LWR-based traffic flow model (Newell's discretization scheme)
  - Traffic Control Model simulates turn movements and signal operations
- Multi-modal routing
  - Individual, prevailing/historical conditions A*
  - Can use GTFS inputs for transit
- Integration of traffic flow and system management components
  - Drivers "see" VMS messages when drive by
  - Drivers get radio messages when tuned in
  - Many other models of agent information (navigation device, look ahead, etc.)
  - Can trigger en-route route switching

Simulation-Based Dynamic Traffic Assignment Process



Key Features Enabled by Disaggregate Integration: En-route Switching



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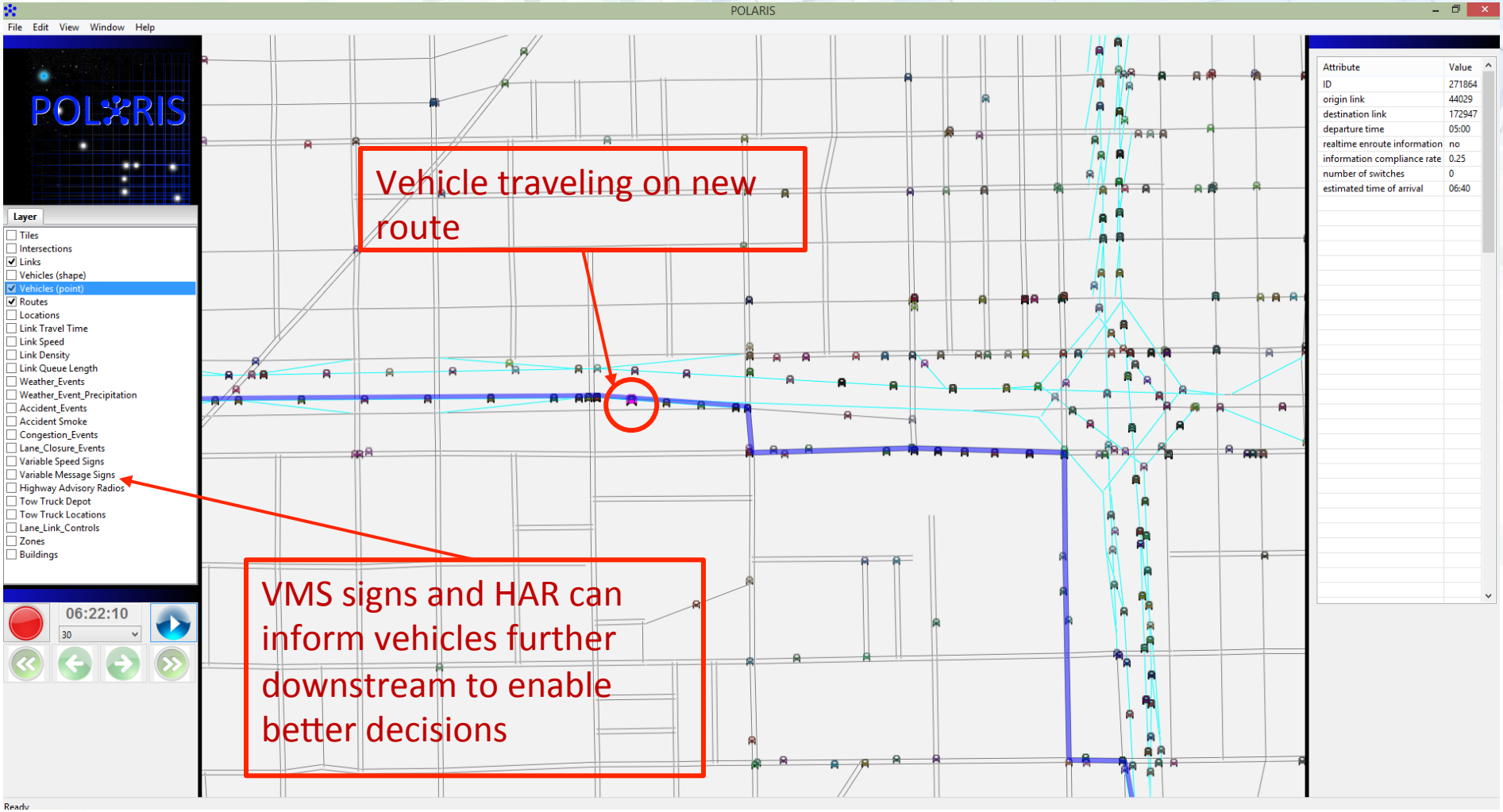
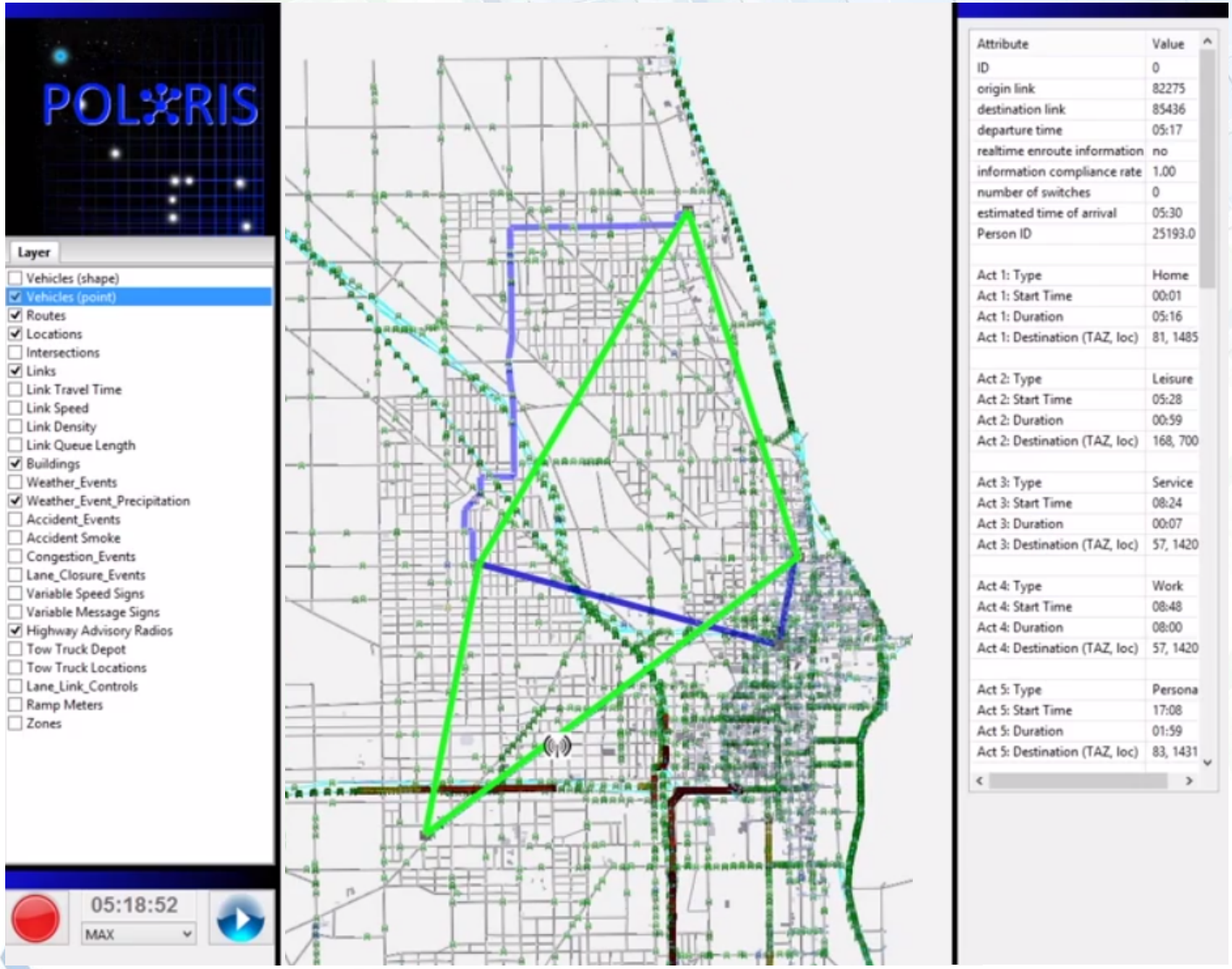


Key Features Enables by Disaggregate Integration: Activity Replanning due to Information



Next steps

- Enhance router to incorporate historical time-dependent information
  - Time-dependent shortest path A* routes
  - Incorporate information on prevailing conditions
  - More realistic information model for individual drivers (instead of perfect knowledge of prevailing conditions)

- Using individualized routing in activity planning decisions
  - Multimodal routed travel times for mode choice
  - Replacing skim matrices with individualized routing for destination decisions
  - Helped by reduction in complexity due to planning constraints

- Incorporating individual history and experiences in network
  - Currently routing individualized only in cost functions
    - all agents have same representation of network conditions
  - How to operationalize storage of individual experience for use in A* router
    - Very challenging and memory intensive

- Microsimulation of driver behavior

Conclusion

- Agent-based integrated model design allows for unique capabilities
  - Enroute route-switching and activity replanning
  - Individual reactions to unexpected events
  - Maintenance of consistency between demand and network models
  - Heterogeneity in agent responses in routing / traffic simulation

- Potentially more useful for certain applications
  - Operational simulations (ITS analysis, CAV fleets, …)
  - Agents responding to unexpected events
  - Emergency planning

- Challenges
  - Computationally intensive to move to fully agent-based behaviors
  - Incorporating agent history in decision making
  - Theoretical underpinnings to solution (i.e. equilibrium)
  - Data availability

Thank You!

For more information go to:
https://github.com/anl-tracc/polaris

or

http://tfresource.org/Polaris